NASA SCIENCE MISSION DIRECTORATE

Earth-Sun System Applied Sciences Program
Carbon Management Program Element
FY 2005-2009 Plan

Version 1.1

March 16, 2005

Expanding and accelerating the realization of economic and societal benefits from Earth-Sun System science, information, and technology

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NASA Science Mission Directorate
Earth-Sun System Division
Applied Sciences Program

Applied Sciences for the Carbon Management Program Element

This document contains the Carbon Management Program Element Plan for Fiscal Years 2005-2009. This plan derives from direction established in the NASA Strategic Plan, the Earth Science Enterprise Strategy, the Space Science Enterprise Strategy, the Earth Science Applications Plan, and OMB/OSTP guidance on research and development. The plan aligns with and serves the commitments established in the NASA Integrated Budget and Performance Document.

The program manager and the Applied Sciences Program leadership have reviewed the plan and agree that the plan appropriately reflects the goals, objectives, and activities for the program element to serve the Applied Sciences Program, the Earth-Sun System Division, NASA, the administration, and society.

(Signature on file) February 11, 2005
Ed Sheffner Date
Program Manager, Carbon Management
Applied Sciences Program
NASA Earth-Sun System Division

(Signature on file) February 11, 2005
Lawrence Friedl Date
Lead, National Applications
Applied Sciences Program
NASA Earth-Sun System Division

(Signature on file) February 11, 2005
Ronald J. Birk Date
Director, Applied Sciences Program
NASA Earth-Sun System Division

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NASA Earth-Sun System Division: Applied Sciences Program
Carbon Management

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Carbon Management Program Element Plan: FY 2005 - 2009

I. Purpose and Scope

This plan describes the Carbon Management Program Element for Fiscal Years 2005 (FY05) through 2009. Included in the plan are the purpose of the program and the strategy to meet the carbon management objectives using the resources available. The plan describes the approach of the program element, including NASA's role in partnerships, the focus on decision support tools, and the extension of NASA Earth-Sun system science results to meet the decision support requirements of partner agencies and organizations. Within the Earth-Sun System Division, this plan functions as a program management tool, describing the program structure, functional mechanisms, performance measures, and general principles that the carbon management activity will follow.

The Carbon Management Program Element is one of twelve Elements in the Applied Sciences Program of NASA'S Earth–Sun System Division. Carbon management is the re-distribution of carbon in terrestrial and aquatic environments through the implementation of policies that affect carbon emissions and sequestration. The Applied Sciences Program extends the use of NASA research results in the carbon cycle to enhance the decision support tools of NASA's operational partners with monitoring and policy mandates regarding carbon emissions and sequestration. The desired outcome is for partner organizations to use project results, such as prototypes and benchmark reports, to enhance their decision support capabilities through the use of Earth-Sun science products.

Carbon management is a key resource management and policy issue of the 21st century. The atmospheric concentration of CO_2 increased by about twenty-five percent during the 20th century and is continuing to increase due to the burning of fossil fuels and changes in land cover and land use. Increases in the atmospheric concentration of CO_2 and other greenhouse gases are likely to produce significant changes in global climate and accompanying changes in the energy and water cycles. These changes will have profound impacts on society and the Earth's ecosystems.

The US Administration launched an initiative in 2001 to address specific elements of the climate change issue.[1] The Carbon Management Program Element responds to the Climate Change

[1] *The initiative augmented the on-going US Global Change Research Program (USGCRP) with the multi-agency Climate Change Research Initiative (CCRI.) In February 2002, the USGCRP and the CCRI were integrated into the Climate Change Science Program (CCSP) and included in a new cabinet level management structure that oversees public investments in climate change science and technology. Also included within the new structure was the Climate Change Technology Program (CCTP) responsible for climate change related technology research and development. The CCSP is directed by the Department of Commerce (DOC) and includes participation from fourteen agencies and departments and the Office of Science and Technology Policy (OSTP). The CCTP is directed by the Department of Energy (DOE) and includes participation from thirteen departments and agencies and OSTP. The CCSP and CCTP report to the interagency Working Group on Climate Change Science and Technology co-chaired by DOC and DOE. The goals and initiatives established by the CCSP and CCTP are the primary manifestation of the US response to the climate change challenge.*

Research Initiative (CCRI) and focuses on carbon emissions and sequestration in terrestrial, oceanic and geologic systems. The Program Element responds to requirements and programs of the operational agencies responsible for implementation of the Climate Change Technology Initiative (CCTI) in regard to the use of NASA sensor systems (e.g., Landsat, Terra/Aqua, Aura, SeaWiFS, Orbiting Carbon Observatory (OCO)) to measure and monitor carbon sequestration in terrestrial, lacustrine and oceanic environments and the flux of carbon among these environments and the atmosphere. Projects sponsored through this Program Element build toward an operational Carbon Management regime that informs resource managers and policy makers of the current state of the distribution of carbon sources and sinks and provides information on near-term and long-term impacts of mitigation actions. Measurements and observations from NASA's Earth orbiting systems are especially useful in integrating the utility of in situ and local measurements to regional and global scales. The Carbon Management Program Element includes carbon emissions commencing in FY06.

The Applied Sciences Program uses observations and measurements acquired by and models developed through NASA carbon research to benchmark assimilation of observations and predictions into decision support tools that support management of carbon sources and sinks by NASA's applications partners. The carbon management element, as with the other elements in Applied Sciences Program, draws upon the research and technology developed through NASA research to support the next generation of integrated system solutions. Carbon management benefits from models developed by NASA centers and laboratories and international collaborations.

In developing a science-based carbon management regime, knowledge of the carbon cycle is exploited to assist operational agencies (e.g., the US Department of Agriculture (USDA), Department of Energy (DOE), Environmental Protection Agency (EPA), and the US Geological Survey (USGS)) fulfill their mandates to manage carbon and to support local, regional, national, and global policy and planning for control of carbon in the environment.

To be current with carbon cycle science, the Carbon Management Program Element draws upon, and contributes to, other program elements in the Applied Sciences Program and other programs in the federal government. The Carbon Management Program Element collaborates with the Carbon Cycle and Ecosystems Focus Area in the Research Program of the Earth-Sun System Division and with the Ecological Forecasting, Water Management, Air Quality, Disaster Management and Homeland Security Program Elements in the Applied Sciences Program. Activities are integrated with the Carbon Cycle Interagency Working Group (CCIWG), the Synthesis and Analysis Report (SAR) 2.2 Agency Executive Committee (the group responsible for interagency compilation of the prospectus for the SAR 2.2 report and management of the North American Carbon Program (NACP)), the CCTP carbon sequestration group, the Focus Area Working Group for carbon of the NASA/USDA Interagency Working Group for Applied Science Applications, and International Working Group on Earth Observations (IWGEO.)

NASA implements the Carbon Management Program Element through partnerships with USDA, DOE and EPA and competitive solicitations. Operational agencies are key members in these partnerships: establishing requirements for decision support systems, monitoring progress,

incorporating results into operational procedures, and on-going, operational use of the tools and systems based on NASA Earth observations, models and research results.

An example of the strategy and implementation of the Carbon Management Program Element is the work sponsored by the Applied Sciences Program at NASA Ames Research Center. CQUEST[1] is an on-line tool developed at Ames. The tool combines NASA Earth observations from MODIS and other sources, a NASA carbon cycle model – Carnagie Ames Stanford Approach (CASA), and NASA systems engineering in a decision support tool now under evaluation by the USDA Forest Service and Natural Resource Conservation Service for use in their mandated carbon reporting activities (see Figure 1). CQUEST also is being evaluated to serve potential applicants to the national program for voluntary sequestration of greenhouse gases (section 1605(b) of the Energy Policy Act of 1992 (EPACT)) and evaluate their land holdings as net emitters or sequesters of carbon before applying to the program[2]. In 2002, DOA invited NASA to participate on a Greenhouse Gas Accounting Rules and Guidelines Working Group, with DOE and EPA, to develop the guidelines for the 1605(b) process.

Scope within NASA and Applied Sciences Program

The Carbon Management Program Element is managed in accordance with, and is guided by, the NASA Strategic Plan and Earth Science Enterprise Strategy. The program element benefits from Earth-Sun system science results and capabilities including Operation System Simulation Experiments (OSSEs), Project Columbia, the Joint Center for Satellite Data Assimilation (JCSDA), the Earth-Sun System Gateway (ESG), and the Transition from Research to Operations (R2O). The program element utilizes initiatives such as the Global Information Grid (GIG) and Federal Enterprise Architecture (FEA) and cooperates with national Earth-Sun laboratories and international programs.

The FY05 President's Budget for the NASA Applied Sciences Program* specifies $54M annually for FY05-FY09 for the National Applications ($24M) and Crosscutting Solutions ($30M) activities. While directly managing a subset of the $24M National Applications budget, the Carbon Management Program Element (and each of the national applications) benefits from the performance results of the $30M budget for Crosscutting Solutions (see Crosscutting Solutions Program Element Plan). The Carbon Management Program Element leverages and extends research results from the approximately $2.1B per year supporting Earth-Sun system science research and development of innovative aerospace science and technology.

Additional information about the NASA Applied Sciences Program can be found at http://science.hq.nasa.gov/earth-sun/applications.

** The National Applications and Crosscutting Solutions components of the Earth Science Applications Theme in the NASA FY05 Integrated Budget & Performance Document*

[1] *"CQUEST" is the name of the tool, not an acronym. The tool is available at: http://geo.arc.nasa.gov/website/cquestwebsite/index.html*

[2] *See http://www.eia.doe.gov/oiaf/1605/background.html for more information on 1605(b).*

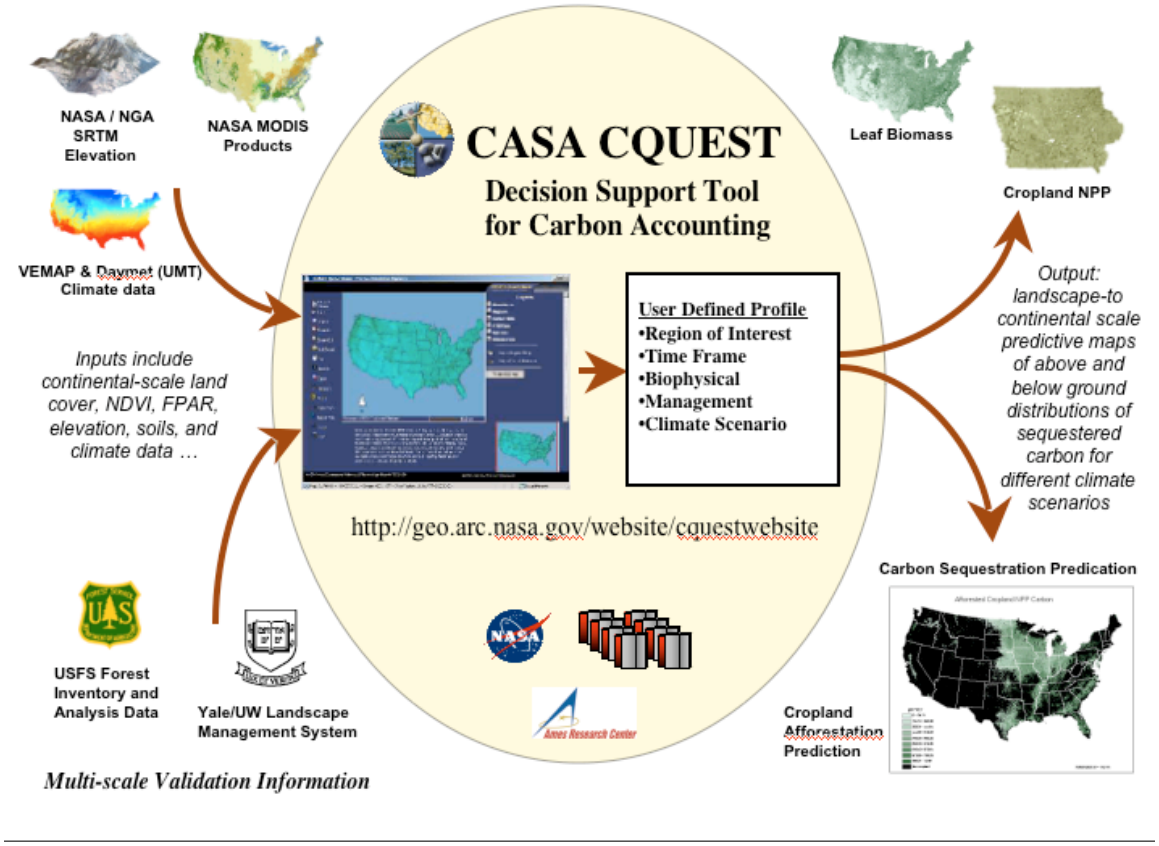


Figure 1: Elements of the CASA CQUEST Tool

The Carbon Management Program Element delivers documented prototype solutions for adaptation and/or adoption by federal, state, and local agencies responsible for carbon management; inter-disciplinary training for key individuals in those partner agencies; and development of protocols for handling acquisition, processing, warehousing, display, and distribution issues in the use of Earth-Sun System science and remote sensing observations for measurement and monitoring of carbon emissions and sequestration.

II. Goals and Objectives

Projects sponsored by the Applied Sciences Program's Carbon Management Program Element in FY05 address objectives 1.1, 1.2 and 3.1 of the NASA 2003 Strategic Plan, and the FY05 NASA Integrated Budget and Performance Document (IBPD) performance measures 5ESA2, 5ESA6, and 5ESA9 (see Table 1).

A. Goals FY05-09:

The Carbon Management Program Element focuses on maximizing the benefit of NASA observations, predictions from model output and systems engineering in decision support systems and tools used by agencies and organizations responsible for policy and resource decisions related to carbon emissions and sequestration – from local to global scales. The goal is

summarized in the Carbon Management Roadmap (Appendix B), which illustrates the development of a robust carbon management regime based on parallel improvements of our understanding of carbon cycle dynamics.

B. FY05 objectives are addressed by the Program Element managing several new projects in FY05 funded through the Carbon Cycle Solicitation of 2004: NRA-04-OES-01. A further objective is to perform a systematic review of the carbon applications projects completed in FY04 and funded under the Carbon Cycle solicitation of 2000-2001: NRA-00-OES-08. Those projects included carbon related activities at local to national levels.

1. CASA CQUEST objectives:
    a. Predictions of NPP annual flux and aboveground biomass pools of carbon in U.S. ecosystems at 1-km spatial resolution (based on the CASA model and MODIS land products)
    b. Predictions of afforestation carbon sequestration rates on existing U.S. agricultural lands at 1-km spatial resolution (based on the CASA model and MODIS land products)
    c. Case studies that demonstrate the application of CQUEST decision support and analysis tools to reporting carbon sequestration projects
2. LEDAPS project at GSFC (co-funded by the Applied Sciences Program and the Research and Analysis Program):
    a. Both surface reflectance and disturbance products are made available to the public via a website (http://ledaps.nascom.nasa.gov/ledaps/ledaps.html) and an ftp site (see http://ledaps.nasacom.nasa.gov/ledaps/products.html for information on accessing data through ftp). Products are produced in a variety of gridded formats, suitable for fine-resolution mapping of forest/agricultural condition, or coarse-resolution grids suitable for carbon modeling.
    b. The schedule of deliverables has been phased to permit multiple rounds of validation and reprocessing. "Beta" releases are pre-validated, and serve to prototype the processing system and give users a flavor of product capabilities and formats. Beta product suites are being generated for selected regions in North America. Provisional releases have undergone some level of validation and quality assurance, and will be generated for all of North America. Validated releases are undergoing thorough validation to be suitable for analysis and modeling activities.
    c. Applications partners are responsible for collaborating on benchmarking the utility of the surface reflectance products for U.S. Forest Service (USFS) activities. The Forest Inventory and Analysis (FIA) provides the project with a short summary report on the evaluation of the products, and any plans for their integration into nominal agency workflows by the end of 2006.
    d. Documentation:
        i. Systems Engineering studies, including:
            1. Evaluation Report documenting current USFS FIA capabilities and processes, and assessing FIA requirements for use of Landsat data products
            2. Validation/Verification Report documenting Landsat Ecosystem Disturbance Adaptive Processing System

(LEDAPS) capabilities and comparing them with FIA requirements
3. Benchmarking Report quantifying improvements made through the use of LEDAPS products and/or processing
4. A final report of work done, jointly written by the teams involved.

e. Algorithm Technical Basis Documents (ATBD) for all product suites, posted online at the Applications Implementation Working Group (AIWG) web site (http://aiwg.gsfc.nasa.gov/)

3. Mississippi State University (MSU): Earth-Sun observing systems for biomass estimation for carbon management and understanding global carbon distributions through next generation data visualization environments
   a. Analyze the utility of ALI, Hyperion, MODIS, and/or other observations relevant to regional/global forest inventory for assessment of carbon distributions. Data will be acquired for highly ground-characterized areas investigated under prior and on-going FWRC/GRI studies. Candidate sites include: Northwest Washington, Central Idaho, East Texas, East-central Mississippi, and Southeast Louisiana.
   b. Investigate feasibility of integration of NASA-generated spacecraft observations into the operational framework of a regional forest inventory system for Mississippi with additional investigation of the extensibility of this system to larger area assessments to monitor carbon balances.
   c. Investigate the potential to apply growth and yield models in a geospatial context to provide landscape-scale predictions of changes in carbon stocks.
   d. Assess and test methods of visualization of carbon distribution through advanced visualization environments.
4. Systematic evaluation of decision support tools, such as the Terrestrial Observation and Prediction System (TOPS), from projects funded by NRA-00-OES-08 and completed in FY04
5. Confirm tasks and schedules for new carbon management projects funded under NRA-04-OES-01 and "Decisions" solicitation.
6. Document in appropriate journals (at least one special edition) and web pages (NASA web site) the progress and capabilities of the Carbon Management Program Element.
7. Represent the Carbon Management Program Element on the NASA/USDA Interagency Working Group.
8. Participate in the NACP and seek projects that match NASA Applied Science capabilities with the measurement and monitoring requirements of the CCTP for carbon emissions and sequestration.

Table 1: Linkage among objectives from the NASA 2003 Strategic Plan, the IBPD and the FY05 Objectives for Carbon Management

NASA Strategic Plan 2003	Objective	FY05 Carbon Mgmt Objective
1.1	Understand how the Earth is changing, better predict change, and understand the consequences for life on Earth.	1,2,3,4
1.2	Expand and accelerate the realization of economic and societal benefits from Applied Science, information and technology	1,2,4
3.3	Improve the Nation's economic strength and quality of life by facilitating the innovative use of NASA technology	1-8
IBPD FY05		
5ESA2	Benchmark at least two national decision support systems using observations from 5 NASA sensors.	1,2
5ESA6	Benchmark at least 5 decision support systems through Earth-Sun science models.	1
5ESA9	Benchmark the use of predictions from two NASA Earth-Sun System science models for use in national priorities such as support for the CCSP and CCTP.	1,2

C. Objectives FY 2006:

1. Evaluate use of CASA CQUEST in decision support tools of operational partners.
2. Benchmark product from LEDAPS project.
3. Begin evaluation of observations and data products from Orbiting Carbon Observatory (OCO)
4. Integrate ocean carbon processes into the Carbon Management roadmap and on the Carbon Management working group.

III. Program Management and Partners

Program Management

Program Manager Carbon Management Element
Mr. Ed Sheffner
Applied Sciences Program
Earth–Sun System Division
NASA Headquarters
Responsibilities:

- Development of and implementation of interagency agreements and partnerships with other organizations.
- Program development including program plans and budgets.
- Development and implementation of solicitations for carbon management tasks.
- Primary responsibility for metrics, performance goals and other performance evaluation criteria.
- Point of contact for CCTP working group on sequestration, NASA/Earth-Sun System Division carbon program (for applications), and NASA/USDA focus area working group on carbon management.

Deputy Program Manager Carbon Management Element
Dr. Carlos Del Castillo
Applied Sciences Program
NASA Stennis Space Center (SSC)
Responsibilities:

- Coordinate and liaison with Program Element Management for Carbon Management tasks at NASA Centers other than Stennis.
- COTR or studies manager (as appropriate) for grants and cooperative agreements related to carbon management and funded by the Earth Science Applications Division through procurement at SSC.
- Management of tasks at SSC related to the Carbon Management Element of the Applied Sciences Program.

B. Partners

The NASA Carbon Management Program Element contributes nodes to a partner network involving government, industry and the academic sector (see Figure 3). This network is improving knowledge of how carbon moves through the environment and is developing and implementing technology to measure carbon emissions, monitor carbon sequestration programs, and provide managers and policy makers with continuous information on which decisions can be made on resource use and policies that impact the global environment. Key nodes in the network (currently involved with the Program Element) include:

NASA HQ partners

Chair: Carbon and Ecosystems Focus Area……...Diane Wickland
Program Manager for Ocean Processes: Earth Science Research Program
……Paula Bontempi
Program Manager for Ecological Forecasting: Applied Sciences Program
……Woody Turner
Program Manager for Water Management: Applied Sciences Program
……Jared Entin
Program Manager for Air Quality: Applied Sciences Program
……Lawrence Friedl
Program Manager for Disaster Management: Applied Sciences Program
……Stephen Ambrose
IPA: Terrestrial Processes ……William Emanuel

Partner agency contacts

USDA:

Bill Hohenstein, Global Change Program Office

Richard Birdsey, US Forest Service, chair, carbon management focus area working group for USDA/NASA Interagency Working Group (http://www.asd.ssc.nasa.gov/pships/usda.aspx?sec=iwg)

Steven Shafer and Paul Doriaswamy, Agricultural Research Service

EPA:

Ken Andrasko, Sequestration Team, Office of Atmospheric Programs

DOE:

Jeff Amthor, Climate Change Research Division, Germantown, MD

USGS:

Tom Loveland, EROS Data Center, Sioux Falls, SD

Government agencies and programs

USDA:

Dr. Richard Birdsey, Global Change Program Office; Sequestration Working Group for CCTI; carbon management focus area for NASSA/USDA interagency working group

DOE:

Dr. Roger Dahlman, Lead in CCTI; Measurement, Monitoring and Verification Working Group for CCTI; lead agency for implementation of 1605(b) guidelines

DOI especially the USGS:

Dr. Tom Loveland, Land cover and land cover change information for carbon sequestration

EPA:

Dr. Jane Leggett

CCSP:

Dr. Steven Shafer, carbon cycle research especially location of sources and sinks (terrestrial and aquatic) and their dynamics

CCTP:

Dr. William Hohenstein, Development and verification of sequestration technology

Carbon Cycle Interagency Working Group:
Dr. David Hoffman, Dr. Kathy Tedesco, NOAA
Dr. Marilyn Buford, Dr. Nancy Cavallero, Dr. Bryce Stokes, USDA
Dr. Rachael Craig, NSF
Dr. Eric Sundquist, USGS
Dr. Lisa Dilling, NCAR
IWGEO

NASA Centers:
ARC:
Dr. Chris Potter and Dr. Ramakrishna Nemani, Modeling of carbon sequestration; enhancement of decision support tools for carbon emissions and sequestration
GSFC:
Dr. Jeff Masek, Calibration of MODIS and Landsat datasets to exploit extended record of Landsat for land cover change and its impact on carbon cycling and carbon management
Johnson Space Center (JSC):
Dr. Kamlesh Lulla, Coral reef studies – link to oceanic sources and sinks
Marshall Space Flight Center (MSFC):
Dr. Steve Goodman, Climate studies and forecasting; impact of climate change on source and sink dynamics
SSC:
Dr. Carlos Del Castillo, Carbon dynamics in near shore and deep oceans; management of carbon projects

Universities (current, active contacts):
Colorado State University (CSU):
Dr. Ingrid Burke, Impact of wild fires on carbon cycling and carbon sequestration
MSU:
Dr. Roger King, Forest structure visualization; monitoring carbon accumulation in forest biomass and soils
University of Georgia (UG):
Dr. Ed Kanemasu, Agricultural decision support and carbon sequestration in developing countries
University of Maryland (UM):
Dr. David Roy, Impact of fires on carbon sequestration

Other Organizations:
Conservation International:
Dr. Marc Steininger, Fires in tropical forests

DAACs and National Labs

The Carbon Management Program Element is based on the observations, models, and systems engineering from NASA's Earth–Sun System Division. The research program for carbon responds to key questions listed in the NASA Strategic Plan 2003 and in the strategic plan for the

Climate Change Science Program. The questions address uncertainties about the carbon cycle in terrestrial and aquatic ecosystems, land use and land use changes that impact the carbon cycle and global climate, and the linkages between ecosystems and global climate.

The Earth–Sun System Division is a participant in the NACP, an element of the CCSP. The goal of the NACP is to reduce the uncertainties about carbon sources and sinks in North America. Activities of this program will extend beyond the next decade and should produce information and models to be integrated through the CCTP for the development of new technologies.

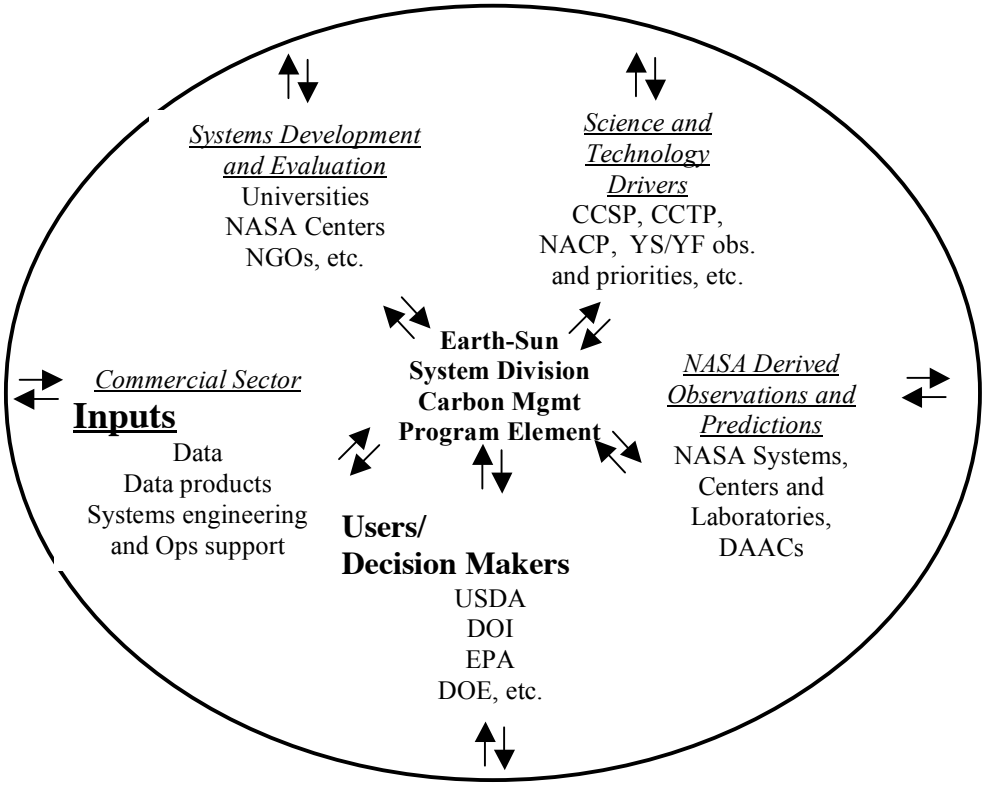


Figure 2: The Applied Sciences Program Node in the Carbon Management Network

The Carbon Management Program Element coordinates input from government, academic and commercial sources with NASA measurements, models, and systems engineering, and integrates NASA's unique assets and capabilities with decision support tools and systems for managing carbon – especially sequestration of carbon in terrestrial systems. The outer ring represents the communication among network members that does not flow through the Earth-Sun System Division Carbon Management Element.

IV. Decision Support Tools

CQUEST and TOPS are two decision support tools that will be benchmarked in coming years in projects funded in FY04 through the Carbon Cycle and Ecosystems solicitation. Projects co-funded by USDA Forest Service, the USDA Agricultural Research Service and the Natural Resources Conservation Service will evaluate the tools against their requirements.

V. Application Activities

A. Projects

1.CASA CQUEST decision support tool:

<table>
<tr><td colspan="4">Project: CQUEST Tool – Integration into DSS</td></tr>
<tr><td colspan="4">The goal of CQUEST is to provide a widely accessible, easy to use web interface through which land managers and policymakers can manipulate NASA observational spacecraft observations and model outputs to improve the management of terrestrial carbon sinks. Overall projects goals include the identification of major forest and agricultural sinks of atmospheric carbon dioxi the U. S. using NASA EOS observational spacecraft observations and ecosyster modeling, the validation of CASA model output with in situ data on carbon sequestration collected by the USDA/USFS, EPA, and Dept. of Interior, the development a common internet-based decision support system (DSS) of carbo sequestration in U. S. ecosystems for users nationwide.

FY05: Integrate 1-km CASA products into CQUEST's web-based delivery tool. Document 1-km CASA products on CQUEST's web-based data information guides.

FY06: Continue collaborations with USDA Forest Service and USDA Natural Resources Conservation Service to benchmark use of CQUEST in USDA decision support tools.</td><td>Budget ($K)

Procurement

FY05 223

FY06 223
FY07 --
FY08 --
FY09 --</td></tr>
<tr><td>Project Manager</td><td>Centers</td><td>Timeframe</td><td>Partners</td></tr>
<tr><td>Chris Potter – NASA/ARC</td><td>ARC, GSFC</td><td>FY03-FY06</td><td>USDA-FS and others</td></tr>
<tr><td>Earth Science Products</td><td colspan="3">AVHRR, MODIS, Landsat, TOPS</td><td>Other Apps.</td></tr>
<tr><td>Deliverables</td><td colspan="3">Contact network, evaluation report(s), validation report(s), results conference(s)</td><td>N/A</td></tr>
</table>

This project fills a void with respect to tools that allow land managers to understand regional to local variation in carbon sequestration potential given different land cover classes and given different climate scenarios that may occur during a reporting period. The tool provides a means to calculate yearly increments of above- and below-ground carbon sequestration. The project team works closely with the USFS to incorporate other tools such as the Carbon On-Line Estimator (COLE) at http://ncasi.uml.edu/.COLE/coleLite.html)/Forcarb, based on Forest Inventory and Analysis (FIA) data, and the Forest Visualization System (FV), which allows for detailed analysis of forest stand changes from basic inventory plot datasets. In this way, the project team is integrating information at multiple scales to address a variety of different user communities from local land managers, to entity portfolio managers, to policy makers.

2. Long-term carbon sequestration history in North America

<table>
<tr><td colspan="5">Project: LEDAPS – Forest Disturbance</td></tr>
<tr><td colspan="4">The goals of this project are to (i) adapt the MODIS MODAPS processing system for use with Landsat imagery; (ii) generate decadal surface reflectance products for Landsat MSS, TM, and ETM+; (iii) map disturbance rate and type (e.g. fire, logging, other) from the Landsat surface reflectance data, and (iv) work with Applied Science Partners to integrate the LEDAPS products and processing system into decision support systems for carbon management and forest inventories. The project will rely primarily on the NASA/EarthSat SDP GeoCover product, which affords cloud-free, orthorectified coverage for North America for decadal epochs centered on 1975, 1990, and 2000. The project will be completed within 4 years. The disturbance maps will be used within carbon accounting and biogeochemical models, while the surface reflectance data will be used within the US Forest Service Forest Inventory Analysis (FIA) program.

FY05 – Complete validation of surface reflectance product suite. Extend disturbance mapping across multiple ecosystems.

FY06-FY07 Both surface reflectance and disturbance products will be made available to the public via a web site and an FTP site. Products will be produced in a variety of gridded formats, suitable for fine-resolution mapping of forest/agricultural condition, or coarse-resolution grids suitable for carbon modeling.</td><td>Budget ($K)

Procurement

FY05 240
FY06 240
FY07 240
FY08 --
FY09 --</td></tr>
<tr><td>Project Manager</td><td>Centers</td><td>Timeframe</td><td>Partners</td><td></td></tr>
<tr><td>Jeff Masek, NASA/GSFC</td><td>GSFC</td><td>FY04-FY07</td><td>USDA-FS</td><td></td></tr>
<tr><td colspan="3">Earth Science Products AVHRR, MODIS, Landsat, TOPS</td><td>Other Apps.</td></tr>
<tr><td colspan="3">Deliverables Evaluation report(s), validation report(s), benchmark report</td><td>N/A</td></tr>
</table>

The goals of this project are to (a) adapt the MODIS Data Processing System (MODAPS**)** processing system for use with Landsat imagery; (b) generate decadal surface reflectance products for Landsat MSS, TM, and ETM+; (c) map disturbance rate and type (e.g. fire, logging, other) from the Landsat surface reflectance data, and (iv) work with Applied Sciences Program partners to integrate the LEDAPS products and processing system into decision support systems for carbon management and forest inventories. The project will rely primarily on the NASA/EarthSat SDP GeoCover product, which affords cloud-free, orthorectified coverage for North America for decadal epochs centered on 1975, 1990, and 2000. The project will be completed within four years. The disturbance maps will be used within carbon accounting and

biogeochemical models, while the surface reflectance data will be used within the US Forest Service Forest Inventory Analysis (FIA) program.

3. Other projects:

a. Carbon sequestration in forests

Aboveground woody biomass accounts for a large proportion of worldwide carbon stocks that can be readily characterized through different remote sensing and geospatial data analysis techniques. The forestry profession has actively measured wood volumes on forestlands for assessment of resource availability for many decades. National inventory programs, such as those run by the USDA Forest Service, provide the only comprehensive information on forest biomass at continental scales. Because most are based on coarse field sampling grids, these programs generally lack a detailed spatial component of biomass distribution information that is critical to carbon budget assessment on a global scale. Spaceborne remote sensing, starting with the Landsat program in 1972, has demonstrated that it is possible to map the distribution of forest resources over large regions. Recent programs of the USGS, USDA Forest Service, and other agencies, have shown that even low-resolution observational spacecraft data such as AVHRR and MODIS are an effective medium to document forest resource distributions at continental scales.

Two tasks at MSU will vector existing projects and expertise into directed research of high National/Global priority to NASA. Task I seeks to develop new techniques for quantification and geospatial characterization of carbon stocks based on remote sensing systems such as ALI, Hyperion and MODIS as supplemented by aerial and ground information on highly characterized sites. Task II will initially utilize existing information to begin development of a visualization environment to achieve better understanding of the distribution and relative amounts of global carbon in forestlands. Once a framework for a geospatial visualization system is in place, the project will then address assimilation of outputs from Task I into a comprehensive system for portraying the spatial and temporal character of global carbon stocks.

Both tasks will be leveraged by existing activities in forest inventory, vectored-disease, and visualization research underway at MSU. MSU is assisting the State of Mississippi in the implementation of a statewide inventory system based on spacecraft observations. The original pilot project was funded by RSTC/NASA. This work is supported through the USDA, CSREES Wood Utilization Research (WUR) program and will likely see continued support through 2006. MSU has also recently assisted in a pilot test of this inventory system in Texas, further reinforcing the potential extensibility of these procedures to regional and continental inventories. The remote sensing component of these efforts is based on Landsat observations but the protocol can be modified, tested, and implemented with the new generation of EOS sensors under consideration for this research program. Given the uncertainty of Landsat, it is imperative that research be directed to investigation of new sensors that will provide for future viability of these inventory efforts.

PI: Dr. Roger King, Mississippi State University/GRI

b. Carbon modeling verification and validation

The Carbon Management Program Element includes systems engineering for validation and verification of datasets and model predictions employed in decision support tools for Carbon

Management. The systems engineering includes: evaluation of data products from existing and planned exploratory missions; identification, base-lining and benchmarking impact of NASA applied sciences on carbon management decisions support tools; and technical and managerial oversight of carbon projects awarded through competitive solicitations conducted by the Earth-Sun System Division.

5. Evaluation of projects completed under NRA-00-OES-08:

- Colorado State University: Application of remotely sensed imagery to assessing the probabilities and carbon consequences of fire – Ingrid Burke*
- Conservation International: Application of a spacecraft model of tropical forest flammability – Marc Steininger*
- NASA/JSC: Distributing Information on Land Cover and Shallow Reefs to Resource Managers – Kamlesh Lulla*
- MSU: Analysis of Competing Vegetation in Forest Management Areas with the Utilization of Remote Sensing Technology – Andy Ezell; Developing Enabling Technologies for Remote Sensing Applications in Agriculture, Forestry, and Transportation Applications – David R. Shaw; Automatic Determination of Tree Crown Shape, Volume, and Density, Developed, Verified, and Visualized using Virtual Environments – Robert Moorhead, Scott Roberts, and David Evans; Development of Procedures for Intensive Stand-level Inventories Combining LIDAR and Spectral Remote Sensing Tools with Traditional Inventory Approaches – David Evans, Scott Roberts, Robert Parker, and Ian Munn**
- University of Arizona: Establishing a Basis for Carbon Management Policy at the State Level: Carbon Dynamics at Site, landscape, and Regional Scales for Arizona State Lands – Stuart Marsh*
- UG: Carbon from communities: a satellite view – Constance Neely*
- UM: Burned area mapping in South Africa: case Study – David Roy*
- University of Montana: Developing a biospheric nowcast and forecast capability for the conterminous US – Ramakrishna Nemani* at ARC
- US Forest Service: Large scale validation of carbon stock and flux estimates from remote sensing – Richard Birdsey*
- Woods Hole Research Center: Remote-sensing applications for forest resource assessment – Scott Goetz*

* Selected through competitive solicitation - NRA-00-OES-08, awarded June, 2001.

** Funded under Challenge Grant to MSU

B. Competitive Solicitation Process

Carbon Management was one of four proposal areas in a solicitation for carbon cycle science and ecosystems in FY04. Projects awarded for Carbon Management under the solicitation have a duration of no more than three years, and address decision support in terrestrial, oceanic or geologic sequestration in response to priorities that emerge from the CCSP and CCTP. Six proposals were selected that included carbon management. The proposals, listed in Table 2, are scheduled to commence in January 2005.

The Carbon Management Element is monitoring progress on proposals awarded in FY04 under the following NASA solicitations: NRA-03-OES-02: "Earth System Science Research using

Data and Products from TERRA, AQUA and ACRIM Satellites" (see Table 3); and NRA-03-OES-03: "Interdisciplinary Science in the NASA Earth–Sun System Division" (see Table 4).

Table 2: Proposals that Address Carbon Management Awarded Under NRA-04-OES-01

Principal Investigator	Organization	Proposal Title
Sam Goward	University of Maryland	North American Forest Disturbance and Regrowth since 1972: Empirical Assessment with Field Measurements and Satellite Remotely Sensing Observations.
Paul Doriaswamy	USDA/Agricultural Research Service	Decision Support Systems for Carbon Management across the US Corn Belt using NASA Remote Sensing Data Products
Richard Birdsey	USDA/Forest Service	Linking Landscape-scale Carbon Monitoring with Forest Management
Tristam West	Dept. of Energy/ Oak Ridge National Lab.	Development of a Framework and Modeling Tool for Spatially-Explicit Full carbon and Greenhouse Gas Accounting at the Regional to National Scale Estimating Net C - Equivalent Flux from U.S. Agriculture.
David Ogle	Colorado State University	CO2 Fluxes between Agricultural Lands and the Atmosphere: Towards more Complete Accounting by Integrating Remote Sensing with Simulation Modeling.
Steve Smith	Joint Global Change Research Institute/Batelle Pacific Northwest National Lab.	Projections of Land Use Change and the Carbon Cycle - Atmospheric Consequences.

Table 3: Carbon Related Projects Funded Under NRA-03-OES-02

Balch, William	The MODIS Ocean Product for Particulate Inorganic Carbon (MOD 25): Refinement of Calcium Carbonate Estimates in the Global Ocean	Bigelow Laboratory
Carlson, Barbara	Understanding Spatial and Temporal Variability in the Earth's Radiative Fluxes Through Analysis of CERES, MODIS, AIRS, and ISCCP Data	Goddard Institute for Space Studies
Chin, Mian	A Global Model Analysis of Anthropogenic Aerosol Radiative Forcing Using Data from Terra and Aqua Satellites, Ground-Based Networks, and In-Situ Measurements	Goddard Space Flight Center
Chopping, Mark	Quantifying Changes in Carbon Pools with Shrub Invasion of Desert Grasslands Using Multi-Angle Data from EOS Terra and Aqua	Montclair State University
Emmons, Louisa	Closing the Carbon Monoxide Budget: Variability in CO Emissions	National Center for Atmospheric Research
Entekhabi, Dara	Global Estimates of Evaporation from Variational Assimilation of Multi-Platform Land Surface Temperature into a Dynamic Model of the Surface Energy Balance	Massachusetts Institute of Technology
Fu, Rong	Investigating the Influences of Vegetation, Biomass Burning, Clouds on Wet Season Onset over the Amazon Using Terra, Aqua in Conjunction with In Situ and Other Satellite Data Sets	Georgia Institute of Technology
Gower, Stith	Applications of MODIS to Resolve the Effects of Global Change on Boreal Forest C Dynamics: Disturbance Versus Climate Warming	University of Wisconsin Madison
Jacob, Daniel	Quantifying the Sources and Global Transport of Combustion Gases and Aerosols Using MOPITT, MODIS, MISR, and Related Satellite Observations	Harvard University
Justice, Christopher	Refinement and Maintenance of the MODIS Fire Product Suite and MODIS Land Discipline Leader	University of Maryland College Park
Marra, John	Primary Productivity from Ocean Color Based on Photosynthetic Quantum Efficiency and Phytoplankton Absorption	Columbia University Lamont Doherty Earth Observatory
McClain, Charles	MODIS Ocean Color Calibration and Validation Support	Goddard Space Flight Center
Nemani, Ramakrishna	Prognostic/Diagnostic Analysis of Land Surface Processes Using Ecosystem Modeling and TERRA/AQUA Products	Ames Research Center
Neuer, Susanne	Analysis of Nutrient Budgets and Carbon Export in the Eastern and Western Subtropical North Atlantic Ocean	Arizona State University
Njoku, Eni	Aqua/AMSR-E Soil Moisture Algorithm and Product Improvements	Jet Propulsion Laboratory
Randerson, James	Using Satellite and Inverse Techniques to Constrain Regional and Global Fire Emissions from 1997 to 2005: An Approach Based on the Carbon Isotope Ratio of Fire Emissions	California Institute of Technology
Ranson, Kenneth	Boreal Zone Forest Type and Structure from EOS Data Sets	Goddard Space Flight Center
Redemann, Jens	Spatial Variability of MODIS and MISR Derived Atmospheric Data Products	Bay Area Environmental Research Institute

Reichle, Rolf	Assimilation of AMSR-E Data and Application to the Initialization of Soil Moisture Reservoirs in a Seasonal Forecasting System	University of Maryland Baltimore County
Remer, Lorraine	Maintenance and Refinement of the Global MODIS Aerosol Products from Terra and Aqua (MOD04/MYD04)	Goddard Space Flight Center
Running, Steven	EOS Algorithm Refinement Proposal-Global Validation and Refinement of the MOD 17 Terrestrial Net Primary Production and MOD 16 Evaporative Index	University of Montana
Saatchi, Sassan	Forest Woody Biomass Carbon Estimates of North America from Synergistic Analysis of MODIS, MISR, and JERS Data in Support of the North American Carbon Program	Jet Propulsion Laboratory
Stramski, Dariusz	Towards Global Monitoring of Particulate Organic Carbon in the Ocean from Satellite Observations	Scripps Institution of Oceanography
Townshend, John	Enhanced Land Cover and Land Cover Change Products from MODIS; An EOS Algorithm Refinement Proposal	University of Maryland College Park
Ustin, Susan	Global Estimation of Canopy Water Content	University of California Davis
Waring, Richard	Predicting Tree Species Diversity Across the Contiguous U.S.A. from Seasonal Patterns in Photosynthesis Derived with Satellite-Driven Models	Oregon State University
Weaver, Clark	Spectral Signatures of Aerosols from Satellite Radiances	Goddard Space Flight Center

Table 4: Carbon Related Projects Funded Under NRA-03-OES-03

Principal Investigator	Proposal Title	Organization
Tian, Hanqin	Linking Multi-Scale Remotely Sensed Data, Field Observations and Biogeochemistry Models to Evaluate Changes in the Terrestrial Ecosystems of China	Auburn University.
Moore, Berrien	Understanding the Changing Carbon, Nitrogen and Water Cycles in the Earth System	Univ. of New Hampshire
Muller-Karger, Frank E.	An Assessment of Global Organic Carbon Flux Along Continental Margins	Univ of. South Florida
Elvidge, Christopher	Development Sprawl Impacts on Terrestrial Carbon Dynamics	NOAA NESDIS-NGDC
Fung, Inez	Studies of Biosphere-Atmosphere Interactions with a GCM with MODIS Spectral Resolution	UC Berkeley
Thompson, David	Understanding the Impacts of Large-Scale Climate Variability on the Global Carbon Cycle.	Colorado St. Univ.
Prinn, Ronald	Testing Trace-Gas Flux Models Using In Situ and Remotely –Sensed Data	MIT
Hofmann, Eileen E.	Eastern U.S. Continental Shelf Carbon Budget: Modeling, Data Assimilation, and Analysis	Old Dominion Univ.
McWilliams, James C.	Simulating and Assessing the Carbon Cycle off the West Coast of North America	UCLA
Ojima, Dennis	Carbon Data Assimilation Modeling: Remote Sensing and Field Observational Constraints of Earth System Carbon Analysis	Colorado St. Univ.
Gao, Yuan	Natural Iron Fertilization in the Ocean and Its Impacts on Ocean Nitrogen Fixation and Carbon Cycles	Rutgers Univ.
Dubayah, Ralph	Characterizing Forest Structure for Assessments of Carbon Cycling and Biodiversity: An Integrated Approach Using Lidar Remote Sensing, Field Studies, and Ecosystem Modeling	Univ. Maryland
Kustas, William	Accounting for Effects of Subpixel Surface Variability on Regional Flux Estimation Using Large Eddy Simulation with Terra and Aqua Sensors	USDA/ ARS

C. Congressionally Directed Activities

There are no congressionally directed activities related to Carbon Management for FY05.

D. Project Management

Program management activities and participation in CCSP/CCTP:

1. Headquarters:

- Participation in carbon cycle working group of the CCSP.
- Participation in the sequestration working group of the CCTP.
- Identification of collaborative projects with USDA working through the NASA/USDA Interagency Working Group and the USDA Remote Sensing Coordinating Committee.
- Member – Carbon Cycle Interagency Working Group

- Contribute to planning, implementation and management of the North American Carbon Program.

2. Ames
- Participate in interagency (USDA, DOE, EPA) Greenhouse Gas Accounting Rules and Guidelines Working Group
- NACP Tier three Site Measurement Guidelines working group.

3. Fellowships: NASA Fellowships for the period FY2002 through 2006 with potential impact on the carbon management program:

Name	Institution	Title
Jeanne Anderson	University of New Hampshire	The Integration of AVIRIS and LIDAR Data for Remote Detection of Forest Structure, Species Composition, and Land-Use Legacies in the White Mountains of New Hampshire.
Isabel Ashton	Stony Brook University	Biological invasions and alterations of the global carbon balance.
Asmeret Asefaw Berthe	University of California Berkeley	Stability and Loss of Buried Soil Organic Carbon
Bryan Brandel	University of Colorado	Regional Scaling of Biogeochemistry in a Larrea tridentata Ecotone: Implications for Carbon Sequestration in the Southwestern United States
Amy Frappier	University of New Hampshire	The Terrestrial Carbon Cycle and ENSO: Evaluating ecosystem processes that amplify the effects of El Nino events on carbon isotope dynamics in a tropical forest
Daniel Hayes	Oregon State University	Mapping Regional Carbon Stocks and Monitoring Carbon Emissions from Land Cover and Land Use Change Along the Mesoamerican Biological Corridor
Emily Hollister	Texas A&M University	Land Use and Land Cover Changes in Temperate Savannas: Impact of Woody Plant Encroachment and Prescribed Fire on Ecosystem Carbon Storage
Laura Koteen	University of California at Berkeley	A Comparison of Carbon Cycling and Material Exchange in Landscapes Dominated by Native and Exotic Grasses in Northern Coastal California
Name	Institution	Title
Desheng Liu	University of California at Berkeley	Systematic Evaluation of Machine Learning Approaches for Remote Sensing Land Cover Classification
Tasha Reddy	Stanford University	Model Resolution Effects on Oceanic Primary Production Estimates and Validation using Remotely Sensed Data: A Case Study for the Ross Sea, Antarctica
Jingfeng Xiao	University of North Carolina	Carbon Sink Due to Woody Encroachment in Non-Forest Areas in the Western U.S. and Impacts of Fire and Climate

E. Additional Activities and Linkages

The Crosscutting Solutions Program—The program consists of functional elements that contribute to all of the National Applications activities. The intention is to have the performance of these functions leverage accomplishment, and therefore the apparent resource investment, to the greatest extent possible into the National Applications partnerships. These functions are: Geoscience Standards and Interoperability, Human Capital Development, Integrated Benchmark Systems, and Solutions Networks. Examples of leveraged activities are:

- *The Earth-Sun System Gateway* is a "portal of portals" providing an access point through an Internet interface to all web-enabled NASA research results.
- *A Rapid Prototyping Center* is a proposed center at Stennis to support NASA and partners in testing and verification of Earth science results in decision support tools.
- *Transition from Research to Operations Network (R2O)* is a network that focuses on systematically transitioning the results of research to operational uses.
- *DEVELOP* is a student-based program for rapidly prototyping solutions for state and local applications and helping students develop capabilities related to applied Earth-Sun science.

NASA and Science Mission Directorate Priorities

- *Federal Enterprise Architecture (FEA)* is a business and performance-based framework to support cross-agency collaboration, transformation, and government-wide improvement.
- *The Global Information Grid (GIG)* is the first stage of a U.S. military global, high-bandwidth, Internet protocol-based communications network (a.k.a., 'the Internet in space').
- *The Joint Center for Satellite Data Assimilation (JCSDA)* is a multi-agency collaboration to accelerate and improve the quantitative use of research and operational observational spacecraft observations in weather and climate prediction models. NOAA (NESDIS, NWS, OAR), NASA, Navy, Air Force, and NSF (through UCAR) collaborate in JCSDA.
- *Metis* is a visual modeling software tool for planning, developing, and analyzing agencies' enterprise architectures. The Applied Sciences Program is using Metis to identify possible linkages between observations, models, and decision support tools to support the IWGEO and NASA/NOAA R2O activities.
- *Observing System Simulation Experiments (OSSEs)* use simulated observations to assess the impacts of future observational spacecraft instruments on weather and climate prediction and provide opportunities to test new designs and methodologies for data gathering and assimilation.
- *Project Columbia* is a NASA-wide project to develop a new, fast supercomputer (using an integrated cluster of interconnected processor systems) to support the Agency's mission and science goals, including enhanced predictions of weather, climate, and natural hazards.

VI. Budget: Fiscal Year 2005

The following table lists the Carbon Management Program budget (procurement) for FY2005:

Carbon	
Project	**FY05 Procurement Allocation ($K)**
CQUEST tool - integration into DSS	$223
GSFC LEDAPS forest disturbance (with YS)	$240
Evaluation of FIA DSTs	$50
Integration on results from carbon studies into fire management systems	$40
CCSP/CCTP	$100
Total	$653

Appendix C lists program-wide budget allocations for FY2005.

VII. Schedule and Milestones

A. FY05

1. CASA CQUEST project
    a. Oct 2005: Meet with USDA Agricultural Research Service (ARS) and university collaborators to develop CQUEST technology and data transfer approaches
    b. Oct-Dec 2004: Generate CASA model products for NPP annual flux, aboveground biomass pools, and afforestation carbon sequestration rates at 1-km spatial resolution
    c. Jan 2005: Meet with USDA Forest Service (FS) and university collaborators to develop CQUEST technology and data transfer approaches
    d. Feb-Sep 2005: Integrate 1-km CASA products into CQUEST's web-based information delivery tools.
    e. Mar-Sep 2005: Document 1-km CASA products on CQUEST's web-based data information guides
2. LEDAPS
    a. December 2004: Develop atmospheric correction and image rectification approaches; prototype forest disturbance mapping algorithm
    b. December 2005: Complete validation of surface reflectance product suite. Extend disturbance mapping across multiple ecosystems
    c. March 2005: Landsat Surface Reflectance Product: Provisional Release / NAM scope
    d. September 2004: Landsat Disturbance and Forest Change Product: Beta Release / Regional scope
3. MSU Carbon Tasks
4. Other tasks:

a. September 2005: Operational implementation of carbon sequestration estimation tool by NASA partner organization.
b. January 2005: Implement carbon management projects from FY04 carbon solicitations
c. September 2005: Report on development of carbon management tools at appropriate national and international conferences, e.g., American Geophysical Union, International Geophysical and Remote Sensing Symposium, and input to appropriate assessments and reports, e.g., 4th IPCC assessment and CCSP reports.

B. FY06

1. Evaluate OCO products through simulations of observations. Baseline impact of OCO observations on existing decision support tools for carbon sequestration and emissions.
2. Evaluate products for soil moisture from Hydros through simulations of data. Baseline impact of Hydros observations on existing decision support tools for carbon sequestration and emissions.
3. Final evaluation of North American carbon sequestration history. Integration of history into carbon sequestration models and tools. Benchmark impact of tools on carbon sequestration tools.

C. FY07

1. Carbon solicitation with carbon management focus on emissions and oceanic sequestration.
2. Integration of OCO and Hydros observations into carbon management decision support tools and systems. Benchmark impact of observations on existing tools and systems.

D. FY08

1. Benchmark integration of new model results and observations in existing carbon management tools.

VIII. Performance Measures

The Carbon Management Program Element team uses performance measures to track progress, identify issues, evaluate projects, make adjustments, and establish results of the Program Element. The program's Goals and Objectives (Section II) state planned achievements. These measures help monitor progress within and across specific activities to ensure the program meets its goals and objectives. The management team analyzes these measures retrospectively in order to made adjustments proscriptively to the program approach and objectives.

The measures are in two categories. Program management measures are internally focused to assess the activities within the program. Performance measures are externally focused to assess if the program activities are serving their intended purpose. In general, the Program Manager uses these measures to evaluate the performance of activities conducted and sponsored by the Program, especially the projects. In addition, the Science Mission Directorate uses this information in preparing IBPD directions and PART responses.

Program Management Measures (Internal):

Inputs	Potential issues and DSTs identified for carbon management – *number, type, range* Eligible partners to collaborate with – *number, type, range* Potential results/products identified to serve carbon management – *number, type, range*
Outputs	Assessments or evaluations of DSTs – *number, range* Assessments of Earth-Sun science results/products to serve DSTs – *number, range* Agreements with partners – *presence* Reports (evaluation, validation, benchmark) – *number, type*
Quality and Efficiency	Earth-Sun science results/products – *number used per DST, ratio of utilized to potential* Agreements – *ratio of agreements to committed partners* Reports – *partner satisfaction, timeliness, time to develop* Reports – *ratio of validations to potential products, ratio of benchmarks to validations*

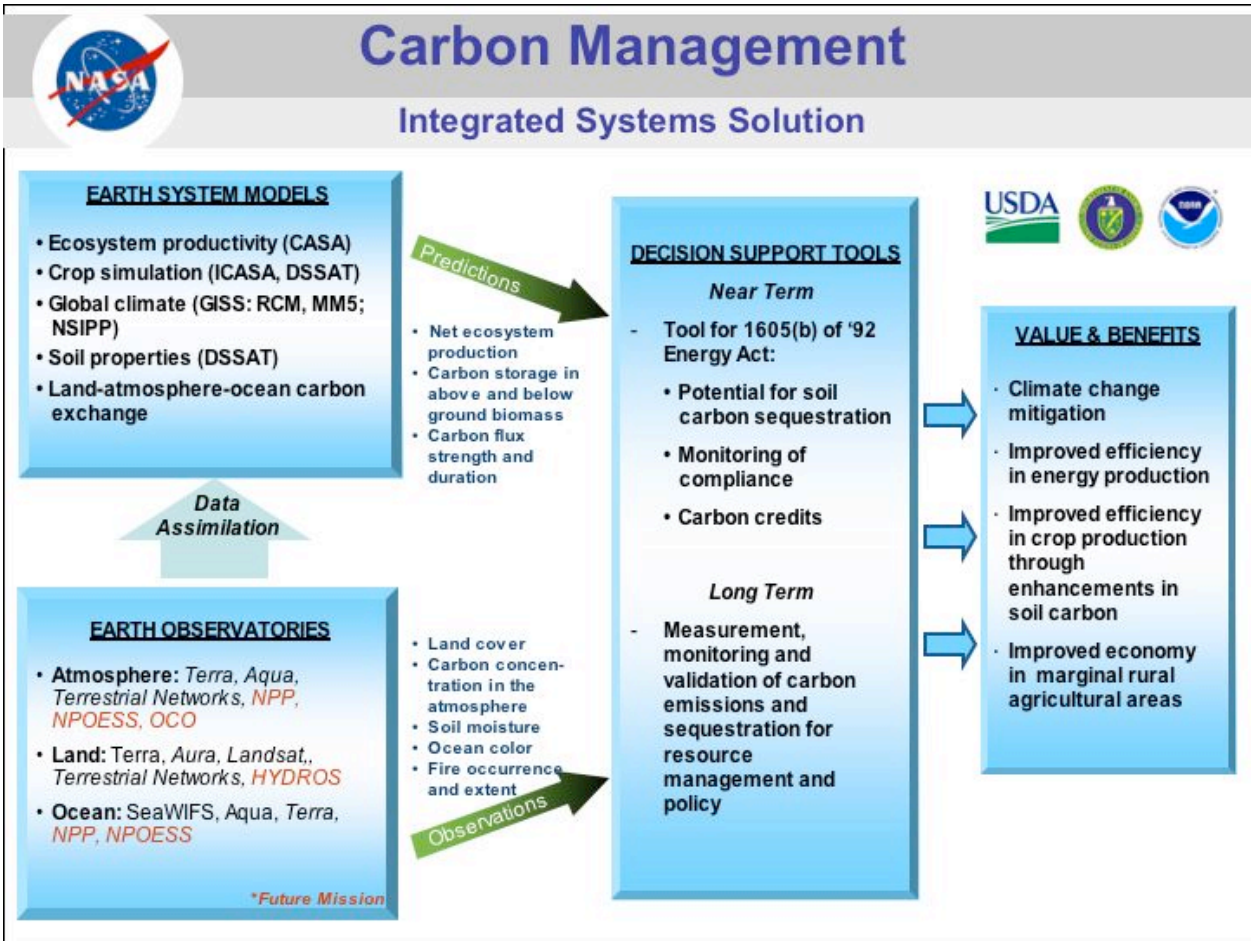
Performance and Results Measures (External):

Outcomes	Earth-Sun science products adopted in DSTs – *number, type, range; use in DST over time* Earth-Sun science products in use – *ratio of products used by partners to reports produced* Partner and DST performance – *change in partner DST performance, number and type of* *public recognition of use and value of Applied Science observatioins in DST*
Impacts	Partner value – *change in partner metrics (improvements in value of partner decisions)*

In addition to the stated measures, the Carbon Management Program Element Manager periodically requests an assessment of its plans, goals, priorities, and activities through external review. The Carbon Management Program Element Team uses these measures along with comparisons to programmatic benchmarks to support assessments of the Science Mission Directorate (e.g. internal NASA reviews and OMB PART).

IX. Appendices

Appendix A. Integrated System Solutions Diagram



Appendix B. Roadmaps

The Carbon Management Program draws upon, and contributes to, the Carbon Science Program of the Earth-Sun System Division. NASA/Earth-Sun System Division-sponsored science supporting climate, weather and natural hazards objectives will generate observations, models and technology that are the primary contributions of the Carbon Management Program to Carbon Management decision support tools and systems. The roadmaps for Carbon Science and Carbon Management are similar - as illustrated below. The major milestones of the science program, such as the introduction of OCO observations and the impact that will have on understanding the flux of carbon among land, ocean and atmosphere, are also milestones for the Carbon Management Program. These roadmaps illustrate the anticipated major objectives and timing for the program in the next ten to fifteen years. The roadmaps were updated in September 2004.

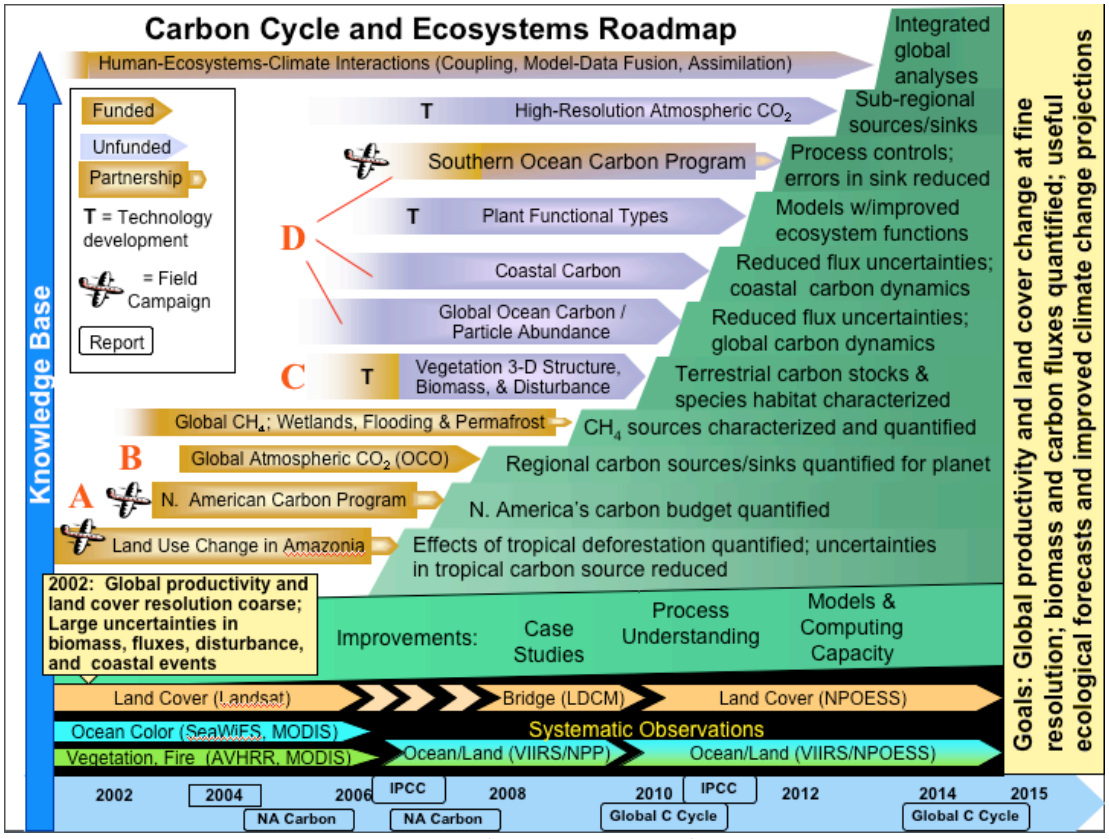


Figure 4. Carbon Science Roadmap

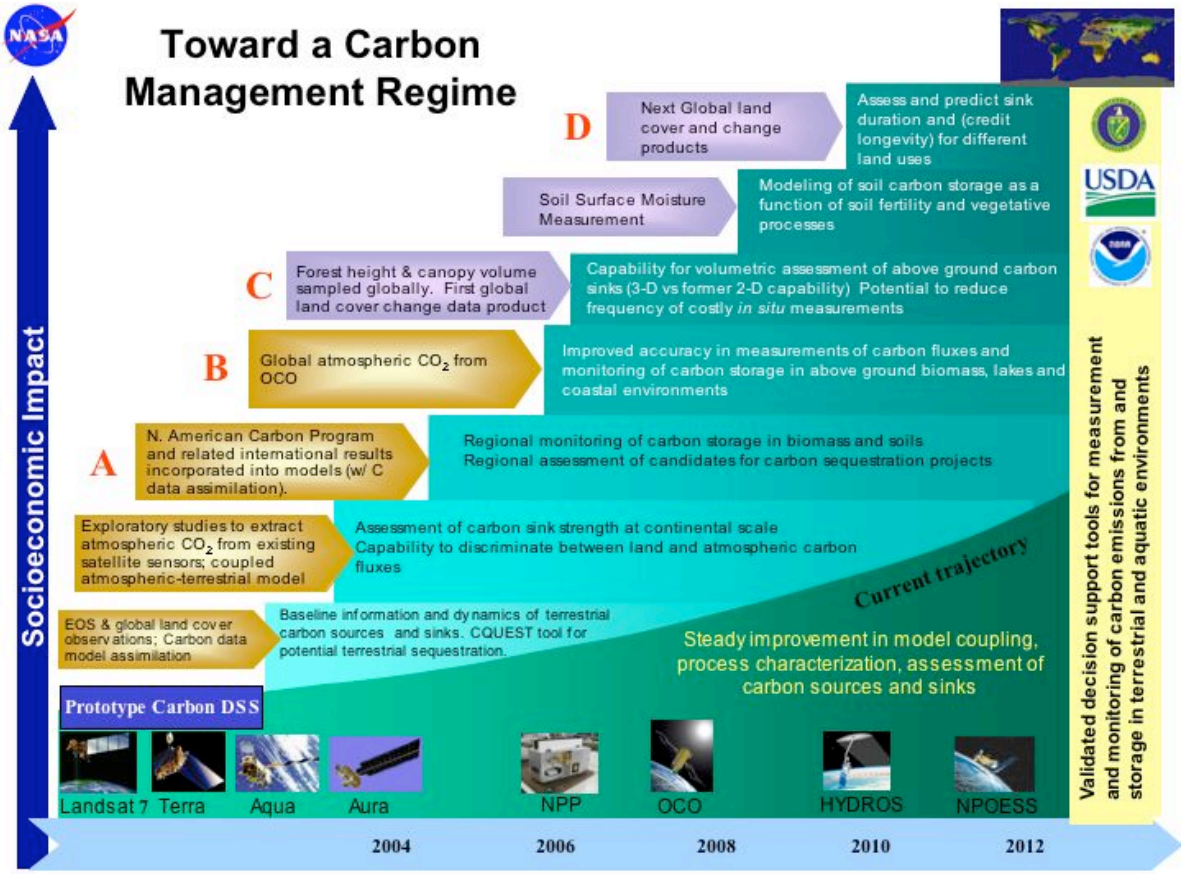


Figure 5. Carbon Management Roadmap

Appendix C. Applied Sciences Program Budgets FY2005-09

The overall program budget allocations are given below to provide the context in which this National Application is conducted. The allocations are based on Agency and program priorities and are subject to change according to the availability of funds and programmatic strategies. All values are in $ thousands.

*NOTE: Allocations include full utilization of the Applied Sciences FY04 carryover of approximately $2.7 million.

Table 1: Applied Sciences Procurement Allocation – FY05

Program Element	FY05 Procurement Allocation
National Applications	
Agricultural Efficiency	$ 467
Air Quality Management	$ 995
Aviation	$ 750
Carbon Management	$ 653
Coastal Management	$ 550
Disaster Management	$ 545
SENH	$ 1,429
Ecological Forecasting	$ 610
Energy Management	$ 775
Homeland Security	$ 205
Invasive Species	$ 205
Public Health	$ 725
Water Management	$ 870
Program Director Discretionary Fund	$ 588
Center Director Discretionary Fund Tax	$ 2,485
National Applications Total	$ 11,852
Crosscutting Solutions	
Integrated Benchmarked Systems	$ 3,529
Solutions Networks	$ 1,200
Competitive Solicitations	$ 7,600
Human Capital Development	$ 700
Geoscience Standards & Interoperability	$ 2,000
Crosscutting Solutions Total	$ 15,029
Applied Sciences Program Procurement Total	***$ 26,881***

Table 3: Applied Sciences Program NASA Institutional Allocations – FY05

NASA Center	FY05 Institutional Cost / National Applications	FY05 Institutional Cost / Crosscutting Solutions	Institutional Total
HQ	$3,773	$7,351	$11,124
ARC	$1,108		$1,108
GSFC	$1,009	$1,094	$2,103
JPL			
LaRC	$1,517	$444	$1,961
MSFC	$1,251	$183	$1,434
SSC	$3,194	$8,689	$11,883
Total	***$11,852***	***$17,761***	***$29,613***

Appendix D. Acronyms and Websites

AIRS	Airborne Infrared Sounder
AIWG	Applications Implementation Working Group
ALI	Advanced Land Imager
AMSR-E	Advanced Microwave Scanning Radiometer-EOS (Japanese)
ARC	Ames Research Center
ARS	Agricultural Research Service
ATBD	Algorithm Technical Basis Documents
AVHRR	Advanced Very High Resolution Radiometer
CANMET	Canadian Meteorological Service
CASA	Carnegie-Ames-Stanford Approach
CCIWG	Carbon Cycle Interagency Working Group
CCRI	Climate Change Research Initiative
CCSP	Climate Change Science Program
CCTI	Climate Change Technology Initiative
CCTP	Climate Change Technology Program
CERES	Clouds and the Earth's Radiant Energy System
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COLE	Carbon On-Line Estimator
COTR	Contracting Officer's Technical Representative
CQUEST	Carbon Query and Evaluation Support Tools
CSREES	Cooperative State Research, Education and Extension Service
CSU	Colorado State University
DAAC	Distributed Active Archive Center (Data Active Archive Center)
DOA	US Department of Agriculture
DOC	US Department of Commerce
DOE	US Department of Energy
ENSO	El Niño - Southern Oscillation
EOS	Earth Observing Systems
EPA	US Environmental Protection Agency
EPACT	Energy Policy Act of 1992
EROS	Earth Resources Observation System
ETM+	Enhanced Thematic Mapper Plus
EVI	Enhanced Vegetation Index
FEA	Federal Enterprise Architecture
FIA	Forest Inventory and Analysis
FPAR	Fraction of Absorbed Photosynthetically Active Radiation
FS	Forest Service
FTE	Full Time Equivalent
FV	Forest Visualization System
FWRC/GRI	Forest and Wildlife Research Center
GCM	Global Climate Model
GIG	Global Information Grid
GRI	Global Reporting Initiative/Geospatial Research Institute
GSFC	Goddard Space Flight Center
IBPD	Integrated Budget and Performance Document
IPA	Independent Pixel Approximation
IPCC	International Panel on Climate Change
ISCCP	International Satellite Cloud Climatology Project

IWGEO	Interagency Working Group on Earth Observations
JCSDA	Joint Center for Satellite Data Assimilation
JSC	Johnson Space Center
LaRC	Langley Research Center
LDAS	Land Data Assimilation System
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
LIDAR	Light Detecting and Ranging
MISR	Multi-angle Imaging Spectro-Radiometer
MODAPS	MODIS Data Processing System
MODIS	Moderate Resolution Imaging Spectroradiometer
MOPITT	Measurements Of Pollution In The Troposphere
MSFC	Marshall Space Flight Center
MSS	Multi-Spectral Scanner (Landsat 1)
MSU	Mississippi State University
NACP	North American Carbon Program
NASA HQ	NASA Headquarters
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NDVI	Normalized Difference Vegetation Index
NESDIS	National Environmental Satellite Data Information Service
NGO	Non Governmental Organization
NPP	NPOESS Preparatory Project/Net Primary Productivity
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research
OCO	Orbiting Carbon Observatory
OMB	Office of Management and Budget
OSSE	Observing System Simulation Experiment
OSTP	Office of Science and Technology Policy
PART	Program Assessment Rating Tool
R2O	Research to Operations Network
RAQMS	Regional Air Quality Modeling system
RSTC	Remote Sensing Applicability with Transportation
SAR	Synthesis and Analysis Report
SDP	Scientific Data Purchase
SEA	State Enterprise Architecture
SSC	Stennis Space Center
TM	Thematic Mapper
TOPS	Terrestrial Observation and Prediction System
UCAR	University Corporation for Atmospheric Research
UGA	University of Georgia
UM	University of Maryland
USDA	US Department of Agriculture
USFS	US Forest Service
USGCRP	US Global Change Research Program
USGS	United States Geological Survey
WUR	Wood Utilization Research

WEBSITES:

COLE: http://ncasi.uml.edu/COLE/coleLite.html

Energy Policy Act of 1992: http://www.eia.doe.gov/oiaf/1605/policy.html

LEDAPS: http://ledaps.nascom.nasa.gov/ledaps/ledaps.html

LEDAPS Data Products: http://ledaps.nascom.nasa.gov/ledaps/products.html

NASA/CASA Project: http://geo.arc.nasa.gov/website/cquestwebsite/index.html

USDA Partnership: http://www.asd.ssc.nasa.gov/pships/usda.aspx?sec=iwg

AIWG: http://aiwg.gsfc.nasa.gov/

Applied Sciences Program: http://science.hq.nasa.gov/earth-sun/applications

DEVELOP: http://develop.larc.nasa.gov

Earth-Sun System Gateway (ESG): http://esg.gsfc.nasa.gov/

Earth-Sun Science System Components: http://www.asd.ssc.nasa.gov/m2m

NASA FY2005 Budget: http://www.ifmp.nasa.gov/codeb/budget2005

Research and Analysis Program: http://science.hq.nasa.gov/earth-sun/science/

Science Mission Directorate: http://science.hq.nasa.gov

Science Strategies: http://science.hq.nasa.gov/strategy/